Should College Algebra be a Coerequisite for Computer Science 1? FECS: Position Paper

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Abstract— *It has long been thought that mathematics background is a factor in a student's success in introductory computer science courses. At our university, College Algebra is a corequisite for Engineering Computer Science I. For some students, meeting this corequisite means that they have to delay taking Computer Science and Computer Engineering courses by one or more semesters until they have achieved the necessary mathematics preparation. We conducted an initial investigation into whether the College Algebra corequisite is actually beneficial, and found mixed results. This prompted us to embark on a larger study. In this paper we discuss the history behind mathematics prerequisites for introductory computer science and computer engineering courses, present the findings from our initial study, and describe our current larger study.*

Keywords: computer science, computer engineering, success, mathematics

1. Introduction

At our university, in order to enroll in Engineering Computer Science I (CS1), students must have concurrently enrolled in College Algebra or have placed into a higher level math course. The reasoning behind this corequisite is that College Algebra provides the problem solving abilities that are required for CS1. In this paper we present our ongoing investigation into whether the College Algebra corequisite is actually helpful.

We offer a Computer Science and a Computer Engineering major. Students from both majors must take the same sequence of introductory computer science courses. CS1 is actually the second course that our Computer Science and Computer Engineering majors take. The first course is Introduction to Computer Science or Introduction to Computer Engineering, courses that provide a survey of their field and introduce basic concepts. Following CS1, students from both majors continue the introductory computer science sequence with Computer Science II (CS2), then Algorithms and Data Structures.

The drawback to the College Algebra corequisite for CS1 is that many students enter our university with poor mathematics preparation from high school. Students who are placed at or below the College Algebra level in the mathematics sequence are not able to take CS1 and can fall behind in the major, requiring extra semesters for graduation. Additionally, students who entered the university intending to major in Computer Science or Computer Engineering may lose interest and switch majors if they are not able to take the major courses in their first couple of semesters at the university. Partially due to these reasons, we allow some students to take College Algebra and CS1 in the same semester.

The University of Texas – Pan American is located in the Rio Grande Valley of South Texas. The university as a whole is pursuing student retention initiatives in order to increase the percentage of students who graduate in six years, which now stands at 42%. Our examination of whether the College Algebra corequisite for CS1 fits into the university's initiative to increase the six-year graduation rate because we are trying to help students complete the major within the standard four-year undergraduate period.

In Section 2 we explore related work and further motivate our study. Section 3 describes our initial investigations into performance in CS1 based on a student's math background. We describe our current study in Section 4, including a description of the questionnaire we administered to the CS1 students in Spring 2013. Section 5 describes our ideas for expanding this study into a study of how students perform in later computer science and computer engineering courses based on their grade in CS1. Finally, we conclude the paper in Section 6.

2. Related Work

Since the early days of the Computer Science field, it has been thought that mathematics background has an impact on a student's success in introductory computer science courses. A number of studies were conducted in the early 1980's that examined the success of students based on mathematics preparation and other background factors. Many of these studies aimed to discover factors that predict success in a computer science major, and planned to use these factors as part of admissions decisions.

Konvalina et. al. conducted a study that compared students who withdrew from beginning computer science courses with those who did not [1]. They examined factors such as educational background, previous computer experience, mathematical ability, and potential for academic success in computer science. Their study was conducted with 382 students in an Introduction to Computer Science course that had one year of high school algebra as a prerequisite. They found that the students who did not withdraw from the course were older, had better performance in high school, had more previous

computer science experience, and had more mathematics background that those students who withdrew from the course. Following this study, the researchers used the findings for advising and placing students. Their initial placement results were that the withdraw rate decreased from 40 percent to 23 percent.

Another study examined first–semester freshman who enrolled in an introductory computer science course, and followed these students through their first year at the university [2]. The authors state that successfully completing the first year of a computer science major is a good indicator of success in the major. At the beginning of their sophomore year, these students were classified into two groups: computer science and related majors, and other majors. The students in the computer science and related majors group were found to have higher SAT math and verbal scores, higher high school rank, and stronger high–school mathematics and science backgrounds.

Butcher and Muth [3] also examined a number of factors in order to find predictors of success in computer science courses. Overall, they found that high school GPA and ACT math scores were the best predictive factor. They also found that the higher level of high school math a student had completed, the more likely that student was to succeed in computer science.

A number of factors that might contribute to success in CS1 were examined in [4]. The study used a questionnaire to collect information from 130 students in a CS1 course. This information was categorized into previous programming experience, previous non-programming computer experience, attribution for success/failure, self–efficacy, comfort level, encouragement from others, work style preference, math background, and gender. These factors were compared with the midterm course grade in order to determine which factors may contribute to success in CS1. The authors found that comfort level in the computer science class was the best predictor of success in the course. A student's math background was the second most important factor. The authors conclude that CS1 professors should create a welcoming atmosphere in the class where students are encouraged to ask questions and seek help. They also recommend that advisors consider math background when advising students whether or not to take CS1.

Another university that faces the same challenge as we do of students entering the university with a weak math background found that these students leave the Computer Science major at a high rate [5]. They define a weak math background as placement in elementary or intermediate algebra when a student enters the university. This definition of weak math background is similar to our College Algebra corequisite. Their approach for increasing retention rates in the Computer Science major was to create a CS0 course that introduced programming concepts using a media–rich programming language called Scratch. The results of their study was that the at–risk students who took CS0 in the first semester of their freshman year had a higher retention rate than the not at–risk first semester freshmen who took CS1 in the same semester.

Much of the prior work examined high school transcripts and standardized test scores in order to gather information about a student's academic background. We are taking a simpler approach of looking at whether a student is enrolled in College Algebra, or has placed into or completed a higher math course. Using a prerequisite course as a indicator of whether a student is likely to succeed in CS1 may be less detailed than looking at a number of other factors. However, with course registration being computerized, we need a simple metric that can be enforced by the registration system when students are signing up for CS1.

Table 1
CS1 PASS RATE OF STUDENTS BASED ON CONCURRENT MATH

Concurrent Math	Num. of Students	Num. Passing CS1	%Passing CS1
College Algebra	14	9	64%
Higher Math	41	25	61%
No Math	54	22	41%
All Students	109	56	51%

3. Initial Investigation

In order to get some idea of how effective our College Algebra corequisite is, we performed an initial examination of how many students passed CS1 based on the math course they took in the same semester as CS1. The reason we focused on the concurrent math course is simply because it was relatively easy to get this data. It would have been more difficult to gather information about the highest math class each student in the class had passed. This means that we have no information about the math preparedness of students who were not concurrently taking a math course. As discussed below, more detailed studies comparing math courses taken and CS1 success are planned for the future.

The grades of 109 CS1 students from the Fall 2012 semester were reviewed. We broke these students into three groups: those who took College Algebra concurrently with CS1, those who took a math class higher than College Algebra concurrently with CS1, and those who were not taking any math class in Fall 2012. We calculated the percentage of the students in each group that passed CS1, along with the overall pass rate. A passing grade in CS1 is considered to be a C or better. These results are shown in Table 1.

We found that students who took College Algebra concurrently with CS1 had a slightly higher pass rate (64%) than those taking a higher math course (61%). The pass rate of students who were not taking a concurrent math course was 41%, and the overall pass rate was 51%. Presumably, the students not taking a concurrent math course had already passed or placed out of College Algebra.

This result raises the question of why students who concurrently take any math class are performing better in CS1 that those not taking a math class. Possible reasons include college preparedness, expectations, knowledge about the appropriate classes to register for each semester, avoidance of math, and bad advising. At this point, we are focusing on determining if the College Algebra corequisite is actually helpful, but we will keep these other factors in mind for future studies.

We plan to expand this study in the future by working with the university to gather a larger and more detailed data set. This will enable us to look at the pass rate of CS1 students based on the highest math course they have completed (or the class they have placed into). We will also expand this study across multiple semesters.

This initial study lead us to explore options for obtaining additional data about student's preparedness for CS1. We decided to gather data by asking students to complete a questionnaire, as described in the next section.

4. Current Study

We are currently engaged in a study involving the students who took CS1 in Spring 2013. We designed a questionnaire to gather information about CS1 students' math and programming background. This questionnaire was administered to the approximately 60 students in two sections of CS1 at the beginning of the Spring 2013 semester. Table 2 shows the list of questions on the questionnaire.

This questionnaire evolved from one that a number of our instructors were informally using to gather general information about the students in their courses. For our purposes, we added the questions about math and programming background. We also added Question 5 (how much do you enjoy math) because one of our instructors feels that enjoyment of math may be a predictor of success in CS1.

Questions 1 through 3 are asking for basic demographic information. We gather information about math background and enjoyment of math in Questions 4 and 5. We then get information about the student's computer science experience. The Introduction to Computer Science and Introduction to Computer Engineering courses provide a survey of the field and a short introduction to programming using the Lego Mindstorms platform. Ideally, these introductory courses will be completed prior to a student taking CS1. However, because of scheduling issues or a student's prior computer science and mathematics experience, some students are allowed to take Introduction to Computer Science/Engineering and CS1 concurrently. Because our CS1 course has a high fail/drop rate, as do many CS1 courses around the world, Question 7 asks whether they have previously taken CS1. We then inquire about previous programming experience in Question 8. The last set of questions were on the original questionnaire that had been used by a number of instructors for many semesters. We ask about their computer, email, internet, and learning software use in Questions 9, 10, 11, and 12. Then Questions 13, 14 and 15 gather information about how busy a student is outside of this class and how much time she expects to dedicate to this class. Questions 16 and 17 are open response questions where a student can express what they hope to gain from CS1 and what difficulties they expect they may face.

We are currently in the process of comparing the questionnaire responses with each student's grade and determining if there is any correlation between math or programming background and the grade received in CS1.

Table 2
CS1 QUESTIONNAIRE

1. Identifying information (name, ID number)
2. Major and minor
3. Classification (freshman, sophomore, junior, senior, other)
4. Current math course, or highest math course taken
5. I enjoy math... (select on scale of 1 to 5)
6. Have you taken Introduction to Computer Science/Engineering? If so, what grade did you receive?
7. Have you taken CS1 before? If so, what grade did you receive?
8. Do you have any programming experience? If so, what language(s)?
9. Do you have a computer at home? If so, is it a laptop or desktop?
10. How frequently do you check your university email?
11. How frequently do you use the internet?
12. How frequently do you check Blackboard (the university's online learning system)?
13. How many hours are you enrolled in this semester?
14. How many hours per week are you working?
15. How many hours do you expect to dedicate to this class outside of class time?
16. What do you hope to gain from taking this class?
17. Are there any difficulties you anticipate that will prevent you from successfully completing this course?

5. Future Directions

In addition to continuing the studies described in Sections 3 and 4, we plan to look into additional success factors in what we call the introductory pipeline in Computer Science. This pipeline includes the CS1, CS2, and Algorithms and Data Structures courses. We would like to improve the pass rate in all of these courses.

Along with other instructors who teach these three courses, we have anecdotally observed that earning a grade of C in one of these courses may predict that a student is likely to struggle in the next pipeline course. This may indicate that students who earn a C in a particular pipeline course are not gaining the knowledge needed to succeed in the next course. The grade of C may also be due to poor study habits or other factors that persist as the student progresses through the pipeline.

6. Conclusions

From the early days of the Computer Science field, there has been interest in discovering what factors indicate that a student is likely to succeed in a Computer Science major. Some educators are interested in these factors in order to assist in admissions decisions. We are more interested in discovering how we can better prepare our students and increase the success rate of students in our Computer Science major.

Mathematics background has been identified by many studies to be an important factor that predicts success in Computer Science. Our CS1 course requires that students are currently taking College Algebra, have completed College Algebra, or have placed into a higher level math course. Because a number of our students place into a lower math course than College Algebra upon entering the university, these students are held back from taking Computer Science or Computer Engineering courses until they have completed one or more semesters of

math. We are currently studying whether the College Algebra corequisite actually helps students succeed in CS1. This study will allow us to set the CS1 prerequisites/corequisites in a way that includes as many students as possible in the course while ensuring that those students are adequately prepared for the course.

References

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